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(54) **PISTON CROWN AND CORRESPONDING PORT GEOMETRY**

(57) An engine assembly including a cylinder wall extending about a cylinder bore is disclosed. A piston slidably received within the cylinder bore includes a ring groove extending about the piston in a ring plane that is transverse to a longitudinal axis of the cylinder bore. A piston ring is received in the ring groove of the piston. A port extends through the cylinder wall to communicate fluid to or from the cylinder bore. The port has an oblique

geometry relative to the ring plane and a plurality of windows that extend at least partially about the cylinder bore in a path that is transverse to the ring plane. The oblique geometry of the port staggers entry and exit of the piston ring relative to the plurality of windows as the piston reciprocates within the cylinder bore. This helps prevent the piston ring from clipping the port.

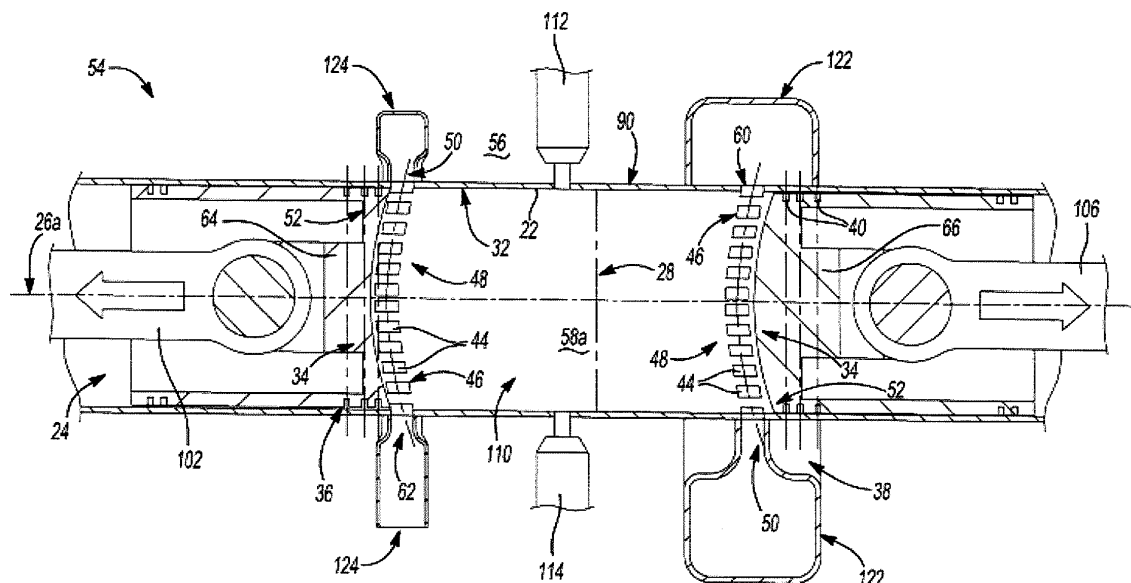


Fig-11

Description

FIELD

[0001] The present disclosure generally relates to internal combustion engines. More particularly, an engine assembly is disclosed where at least one of the inlet and exhaust ports has an oblique geometry.

BACKGROUND

[0002] This section provides background information related to the present disclosure which is not necessarily prior art.

[0003] In typical internal combustion engines, a cylinder is defined by a cylinder wall. A piston is slidably disposed within the cylinder. Combustion forces within the cylinder of the internal combustion engine act on the piston and drive the piston in a reciprocating manner. The piston includes at least one piston ring received in a corresponding ring groove that extends about the piston. The piston ring contacts the cylinder wall and thus seals the piston against the cylinder wall. To maintain this seal, the piston ring exerts outward pressure against the cylinder wall. If the outward pressure exerted by the piston ring is too low, then the combustion forces can drive combustion gases between the cylinder wall and the piston. This unwanted condition, commonly referred to as "blow-by," results in power loss and can cause engine damage. Accordingly, piston rings are designed to exert considerable outward pressure against the cylinder wall.

[0004] Many internal combustion engines, including many opposed-piston engines, have inlet ports and exhaust ports disposed along the cylinder wall. The inlet ports deliver an intake charge of either air or an air/fuel mixture into the cylinder for combustion. The exhaust ports transport the exhaust gases that are produced by combustion out of the cylinder so that a new intake charge can enter the cylinder. Typically, the inlet and exhaust ports are opened and closed by the piston as it passes by the inlet and exhaust ports. Such designs are commonly categorized as two-stroke engines; however, it should be appreciated that the subject disclosure is not limited to just two-stroke engines. One problem that exists with any engine that has an inlet port or an exhaust port that is opened and closed by the piston is that the piston ring has a tendency to catch the port as the piston reciprocates within the cylinder. This condition is commonly referred to as "ring clipping." Generally, the entire piston ring enters and exits the port at the same time and the outward pressure exerted by the piston ring causes a portion of the piston ring to migrate outwardly from the ring groove and into the port. Small migrations of the piston ring leads to excessive wear of the piston ring and/or the inlet and exhaust ports resulting in shorter engine life and compression loss. Larger migrations of the piston ring can cause catastrophic ring and piston failure resulting in expensive engine damage.

[0005] The ring clipping problem can be especially problematic in opposed-piston engines because opposed-piston engines often utilize high compression ratios, requiring piston rings that exert more outward pressure on the cylinder wall to maintain a seal. Opposed-piston engines generally include two pistons housed within each cylinder that move in an opposed, reciprocal manner within the cylinder. In this regard, during one stage of operation the pistons are moving away from one another within the cylinder and during another stage of operation the pistons are moving towards one another within the cylinder. As the pistons move towards one another within the cylinder, they compress and, thus, cause ignition of a fuel/air mixture disposed within the cylinder. In so doing, the pistons are forced apart from one another, thereby exposing the inlet ports and the exhaust ports. Exposing the inlet ports draws air into the cylinder and this in combination with exposing the exhaust ports expels exhaust, thereby allowing the process to begin anew. When the pistons are forced apart from one another, connecting rods coupled to each piston transfer the linear motion of the pistons within the cylinder to one or more crankshafts that are coupled to the connecting rods. The forces imparted on the connecting rods thus cause rotation of the crankshafts which, in turn, cause rotation of wheels of a vehicle in which the internal combustion engine is installed. However, it should be appreciated that the ring clipping problem can occur in any engine that has a port in the cylinder wall that is opened and closed by movement of a piston. Accordingly, the subject disclosure is not limited to opposed piston engines, but is applicable to a wide variety of different engine types, including without limitation, compression-ignition engines (e.g. diesel engines), spark-ignition engines, two-stroke engines, and four-stroke engines of various cylinder arrangements.

SUMMARY

[0006] This section provides a general summary of the disclosure, and is not a comprehensive disclosure of its full scope or all of its features.

[0007] In accordance with one aspect of the subject disclosure, an engine assembly is provided. The engine assembly includes a cylinder wall extending about a cylinder bore and a piston slidably received within the cylinder bore. The cylinder bore defines a longitudinal axis and the piston is movable along this longitudinal axis. The piston includes at least one ring groove that extends about the piston in a ring plane that is transverse to the longitudinal axis. At least one piston ring is received in the at least one ring groove of the piston. The engine assembly further includes at least one port extending through the cylinder wall that is open to the cylinder bore. The at least one port has an oblique geometry relative to the ring plane. The at least one port includes a plurality of windows that extend at least partially about the cylinder bore in a path that is oblique to the ring plane. Accord-

ingly, the oblique geometry of the at least one port staggers entry and exit times of the at least one piston ring relative to the plurality of windows of at least one port as the piston reciprocates within the cylinder bore.

[0008] In accordance with another aspect of the subject disclosure, an opposed piston engine is provided. The opposed piston engine includes an engine block that has a cylinder wall extending about and defining a first cylinder. The first cylinder has a first longitudinal axis. The first cylinder also includes a first inlet port and a first exhaust port, each being disposed in the cylinder wall. The first exhaust port is longitudinally spaced from the first inlet port. A pair of first pistons including a first piston and a first opposing piston are slidably disposed within the first cylinder. The pair of first pistons are movable along the first longitudinal axis toward one another in a first mode of operation and away from one another in a second mode of operation. Each piston includes a piston crown and at least one ring groove that extends about each piston in a ring plane that is perpendicular to the first longitudinal axis. At least one piston ring is received in the at least one ring groove of each piston. At least one of the first inlet port and the first exhaust port has an oblique geometry thereby defining at least one oblique port. The at least one oblique port has a plurality of windows extending at least partially about the first cylinder in a path that is oblique to the ring plane. Accordingly, the oblique geometry of the oblique port staggers entry and exit times of the at least one piston ring relative to the plurality of windows of the at least one oblique port as the pair of first pistons translate within the first cylinder.

[0009] The disclosed engine design solves the ring clipping problem because the oblique geometry of the port is not aligned with the ring plane. Entry and exit of the piston ring does not occur abruptly along the entire piston ring like in known designs, but occurs gradually along the piston ring. Due to the oblique geometry of the port, there is no point in piston travel where the entire piston ring transitions from the cylinder wall to the port or where the entire piston ring transitions from the port to the cylinder wall. Instead, the piston ring crosses only some of the windows in the plurality of windows of the port at a given moment in time. For these reasons, the oblique geometry of the port advantageously increases ring life, decreases wear, and improves reliability.

BRIEF DESCRIPTION OF THE DRAWINGS

[0010] Other advantages of the present invention will be readily appreciated, as the same becomes better understood by reference to the following detailed description when considered in connection with the accompanying drawings wherein:

Figure 1 is a partial perspective view of an exemplary engine assembly constructed in accordance with the subject disclosure where the piston has a concave piston crown;

Figure 2 is a partial perspective view of an exemplary engine assembly constructed in accordance with the subject disclosure where the piston has a domed piston crown;

Figure 3 is a partial plane view of an exemplary cylinder constructed in accordance with the subject disclosure where the cylinder wall has been unwrapped to illustrate the oblique geometry of the inlet and exhaust ports;

Figure 4 is a front elevation view of the exemplary piston illustrated in Figure 1;

Figure 5 is a partial cross-section view of the exemplary piston and port geometry illustrated in Figure 1 where the ports are open to the cylinder bore;

Figure 6 is a partial cross-section view of the exemplary piston and port geometry illustrated in Figure 1 where translation of the piston is closing the ports;

Figure 7 is a partial cross-section view of the exemplary piston and port geometry illustrated in Figure 1 where the ports are closed to the cylinder bore by the piston;

Figure 8 is a partial cross-section view of an exemplary opposed-piston engine constructed in accordance with the subject disclosure where the first piston and the first opposing piston are spaced apart at a bottom dead-center position;

Figure 9 is a partial cross-section view of the exemplary opposed-piston engine illustrated in Figure 8 where the first piston and the first opposing piston are nested together at a top dead-center position;

Figure 10 is a partial perspective view of another exemplary opposed-piston engine constructed in accordance with the subject disclosure where an engine block defines multiple cylinders;

Figure 11 is a partial cross-section view of the first cylinder of the exemplary opposed-piston engine illustrated in Figure 10; and

Figure 12 is a partial cross-section view of the second cylinder of the exemplary opposed-piston engine illustrated in Figure 10.

DETAILED DESCRIPTION

[0011] Referring to the Figures, wherein like numerals indicate corresponding parts throughout the several views, an engine assembly **20** is disclosed.

[0012] Example embodiments are provided so that this disclosure will be thorough, and will fully convey the scope to those who are skilled in the art. Numerous specific details are set forth such as examples of specific components, devices, and methods, to provide a thorough understanding of embodiments of the present disclosure. It will be apparent to those skilled in the art that specific details need not be employed, that example embodiments may be embodied in many different forms and that neither should be construed to limit the scope of the disclosure. In some example embodiments, well-known processes, well-known device structures, and well-

known technologies are not described in detail.

[0013] The terminology used herein is for the purpose of describing particular example embodiments only and is not intended to be limiting. As used herein, the singular forms "a," "an," and "the" may be intended to include the plural forms as well, unless the context clearly indicates otherwise. The terms "comprises," "comprising," "including," and "having," are inclusive and therefore specify the presence of stated features, integers, steps, operations, elements, and/or components, but do not preclude the presence or addition of one or more other features, integers, steps, operations, elements, components, and/or groups thereof. The method steps, processes, and operations described herein are not to be construed as necessarily requiring their performance in the particular order discussed or illustrated, unless specifically identified as an order of performance. It is also to be understood that additional or alternative steps may be employed.

[0014] When an element or layer is referred to as being "on," "engaged to," "connected to," or "coupled to" another element or layer, it may be directly on, engaged, connected or coupled to the other element or layer, or intervening elements or layers may be present. In contrast, when an element is referred to as being "directly on," "directly engaged to," "directly connected to," or "directly coupled to" another element or layer, there may be no intervening elements or layers present. Other words used to describe the relationship between elements should be interpreted in a like fashion (e.g., "between" versus "directly between," "adjacent" versus "directly adjacent," etc.). As used herein, the term "and/or" includes any and all combinations of one or more of the associated listed items.

[0015] Although the terms first, second, third, etc. may be used herein to describe various elements, components, regions, layers and/or sections, these elements, components, regions, layers and/or sections should not be limited by these terms. These terms may be only used to distinguish one element, component, region, layer or section from another region, layer or section. Terms such as "first," "second," and other numerical terms when used herein do not imply a sequence or order unless clearly indicated by the context. Thus, a first element, component, region, layer or section discussed below could be termed a second element, component, region, layer or section without departing from the teachings of the example embodiments.

[0016] Spatially relative terms, such as "inner," "outer," "beneath," "below," "lower," "above," "upper," and the like, may be used herein for ease of description to describe one element or feature's relationship to another element(s) or feature(s) as illustrated in the figures. Spatially relative terms may be intended to encompass different orientations of the device in use or operation in addition to the orientation depicted in the figures. For example, if the device in the figures is turned over, elements described as "below" or "beneath" other elements or features would then be oriented "above" the other el-

ements or features. Thus, the example term "below" can encompass both an orientation of above and below. The device may be otherwise oriented (rotated 90 degrees or at other orientations) and the spatially relative descriptors used herein interpreted accordingly.

[0017] Referring to Figures 1 and 2, an engine assembly **20** is illustrated. It should be appreciated that such an engine assembly **20** comprises part of a larger internal combustion engine. The internal combustion engine may be of a variety of different types, including without limitation, a two-stroke engine or a four-stroke engine. Further, the internal combustion engine may be designed to run on one or more of a variety of different fuels, including diesel fuel (e.g. a compression ignition engine) and gasoline (e.g. a spark ignition engine).

[0018] The engine assembly **20** includes a cylinder wall **22** that extends annularly about a cylinder bore **24**. In this way, the cylinder wall **22** defines a size and shape of the cylinder bore **24**. The cylinder bore **24** has a longitudinal axis **26** that extends co-axially through the cylinder bore **24**. The cylinder bore **24** also has a bore cross-section **28** that is perpendicular to the longitudinal axis **26**. While the cylinder bore **24** and thus the bore cross-section **28** may have a variety of different shapes, by way of example and without limitation, the bore cross-section **28** may have a circular perimeter.

[0019] A piston **30** is slidably received within the cylinder bore **24** for reciprocal movement therein along the longitudinal axis **26** between a bottom dead-center position and a top dead-center position. As is commonly known in the internal combustion engine field, the term "bottom dead-center" describes a position of the piston **30** where the piston **30** is at the bottom of its stroke (i.e. where the piston **30** is closest to the engine's crankshaft). Similarly, the term "top dead-center" describes a position of the piston **30** where the piston **30** is at the top of its stroke (i.e. where the piston **30** is farthest from the crankshaft). The piston **30** translates within the cylinder bore **24** by sliding relative to the cylinder wall **22** and more specifically an inner surface **32** of the cylinder wall **22**. Thus, it should be appreciated that the inner surface **32** of the cylinder wall **22** faces the piston **30**. The piston **30** generally includes a piston crown **34** that spans the bore cross-section **28**. Notwithstanding the fact that the piston crown **34** spans the bore cross-section **28**, it should be appreciated that there may be a clearance gap between the piston crown **34** and the inner surface **32** of the cylinder wall **22**. The piston crown **34** shown in Figure 1 has a concave shape while the piston crown **34** shown in Figure 2 has a domed shape. The piston **30** also includes at least one ring groove **36** that extends annularly about the piston **30** in a ring plane **38** that is perpendicular to the longitudinal axis **26** and parallel to the bore cross-section **28**.

[0020] As best seen in Figure 4, at least one piston ring **40** is received in the at least one ring groove **36**. The piston ring **40** has an annular shape and has a cross-sectional profile that extends radially within the ring plane

38 from the piston **30** to the inner surface **32** of the cylinder wall **22**. Accordingly, the piston ring **40** abuts the inner surface **32** of the cylinder wall **22** and seals against the inner surface **32** of the cylinder wall **22** to prevent the blow-by of combustion gases. Of course the piston **30** may include multiple ring grooves **36**, each receiving one of several piston rings **40**. In Figure 4, several piston rings **40** are illustrated defining multiple ring planes **38** that are generally parallel with one another.

[0021] As illustrated in Figures 1 and 2, the cylinder wall **22** has one or more ports **42a**, **42b** that extend through the cylinder wall **22** and that are open to the cylinder bore **24**. For example and without limitation, the cylinder wall **22** may include two ports **42a**, **42b** where one of the ports **42a** operates to draw exhaust gases from the cylinder bore **24** and the other one of the ports **42b** operates to supply intake air or an air/fuel mixture to the cylinder bore **24**. Each port **42a**, **42b** includes a plurality of windows **44** that are circumferentially spaced from one another about the cylinder wall **22**. Each window **44** of the plurality of windows **44** may have a window perimeter **46** that extends about each window **44** of the plurality of windows **44** adjacent the inner surface **32** of the cylinder wall **22**. The window perimeters **46** of the plurality of windows **44** may cooperatively define the ports **42a**, **42b**.

[0022] As best seen in Figure 3, the ports **42a**, **42b** each have an oblique geometry **48** relative to the ring plane **38**. The term "oblique geometry," as used herein, means that the ports **42a**, **42b** extend about the cylinder bore **24** in a path **50** that is oblique to (i.e. forms an oblique angle with) the ring plane **38**. This oblique geometry **48** staggers entry and exit times of the at least one piston ring **40** relative to the plurality of windows **44** of the ports **42a**, **42b** as the piston **30** reciprocates within the cylinder bore **24** between the bottom dead-center position and the top dead-center position. In other words, the at least one piston ring **40** crosses the window perimeters **46** of the plurality of windows **44** at varying time intervals to reduce the likelihood of ring clipping. For example, the at least one piston ring **40** first crosses the windows **44** disposed toward the center of Figure 3 as the piston **30** translates upwards along the cylinder wall **22** illustrated in Figure 3. As the piston **30** continues its upward movement, the at least one piston ring **40** gradually crosses the windows **44** staggered to each side of the centrally located windows **44**. The at least one piston rings **40** transitions into full contact with the inner surface **32** of the cylinder wall **22** in this same gradual manner. While the oblique geometry **48** of the ports **42a**, **42b** may take a variety of different shapes, by way of example and without limitation, the path **50** in which the ports **42a**, **42b** extend circumscribes the cylinder bore **24** and may be a sinusoidal path as shown in Figure 3.

[0023] As shown in Figures 1, 2 and 4, the piston crown **34** has a periphery **52** adjacent the cylinder wall **22** that forms an oblique angle with the ring plane **38** and that has a shape corresponding to the oblique geometry **48**

of the ports **42a**, **42b**. For example, the periphery **52** of the concave piston crown **34** of Figure 1 corresponds to the oblique geometry **48** of the port **42a** shown in Figure 1. Similarly, the periphery **52** of the domes piston crown **34** of Figure 2 corresponds to the oblique geometry **48** of the port **42b** shown in Figure 2. With reference to Figures 5-7, the shape of the periphery **52** of the piston crown **34** opens and closes the plurality of windows **44** at substantially the same time along the oblique geometry **48** of the at least one port **42** as the piston **30** reciprocates within the cylinder bore **24** between the bottom dead-center position and the top dead-center position. By way of example, the periphery **52** of the piston crown **34** may open and close the plurality of windows **44** of the at least one port **42** within 0.2 milliseconds (ms) of one another, where the internal combustion engine is operating at a speed of 2100 revolution per minute (RPM), has a stroke of 210 millimeters (mm), and a port placement to piston crown tolerance of plus or minus (+/-) 1 millimeter (mm). In Figures 5-7, the piston **30** is moving from left to right. In Figure 5, the periphery **52** of the piston crown **34** is approaching the plurality of windows **44** of port **42a**. Although the oblique geometry **48** of port **42a** staggers entry and exit times of the at least one piston ring **40**, it can be seen in Figure 5 that the shape of the periphery **52** of the piston crown **34** corresponds with the oblique geometry **48** of port **42a** and allows all portions of the periphery **52** of the piston crown **34** to concurrently approach the plurality of windows **44**. In Figure 6 the piston **30** has moved such that the periphery **52** of the piston crown **34** is closing the plurality of windows **44** at substantially the same time across port **42a**. Finally, Figure 7 shows the shape of the periphery **52** allows the piston crown **34** to close the plurality of windows **44** of port **42a** at substantially the same time. Accordingly, the disclosed engine assembly **20** provides a solution to the ring clipping problem without changing the timing of the opening and closing of port **42a**. The same teachings may be applied to port **42b** in configurations where the cylinder wall **22** has two ports **42a**, **42b**.

[0024] Figures 8-10 illustrate an opposed-piston engine **54** that utilizes the disclosed piston crown and port geometry. The opposed-piston engine **54** includes an engine block **56** with a cylinder wall **22** that extends about and defines a first cylinder **58a**. The first cylinder **58a** has a first longitudinal axis **26a** extending co-axially through the first cylinder **58a**. The first cylinder **58a** also has a first inlet port **60** and a first exhaust port **62** that is longitudinally spaced from the first inlet port **60**. Both the first inlet port **60** and the first exhaust port **62** extend through the cylinder wall **22** and are open to the first cylinder **58a**. An intake charge of air or an air/fuel mixture is supplied to the first cylinder **58a** of the opposed-piston engine **54** through the first inlet port **60**. This intake charge undergoes combustion within the first cylinder **58a**. Combustion of the intake charge produces exhaust gasses, which exit the first cylinder **58a** through the first exhaust port **62**.

[0025] As best seen in Figures 8 and 9, the opposed-

piston engine **54** has a pair of first pistons **64, 66** including a first piston **64** and a first opposing piston **66** that are slidably disposed within the first cylinder **58a**. More particularly, the first piston **64** and the first opposing piston **66** are movable along the first longitudinal axis **26a** toward one another in a first mode of operation and away from one another in a second mode of operation. In embodiments where the opposed-piston engine **54** is a two-stroke engine, the intake charge is compressed by the pair of first pistons **64, 66** during the first mode of operation. This compression may cause the intake charge to ignite when the pair of first pistons **64, 66** are at or near the top dead-center position shown in Figure 9. The resulting combustion of the intake charge drives the pair of first pistons **64, 66** apart during the second mode of operation. Alternatively, spark ignition may be used to control ignition of the intake charge during the first mode of operation. As the pair of first pistons **64, 66** are driven apart during the second mode of operation, the pair of first pistons **64, 66** pass by the first inlet port **60** and first exhaust port **62** as the pair of first pistons **64, 66** move to the bottom dead-center position shown in Figure 8. In accordance with the outward movement of the pair of first pistons **64, 66**, the first inlet port **60** and the first exhaust port **62** are opened and become exposed to the first cylinder **58a**. Exhaust gases thus exit the first cylinder **58a** through the first exhaust port **62** and a new intake charge enters the first cylinder **58a** through the first inlet port **60** such that the engine cycle may begin anew.

[0026] Each piston of the pair of first pistons **64, 66** includes a piston crown **34** and one or more ring grooves **36**. The ring grooves **36** extend about each piston of the pair of first pistons **64, 66** in respective ring planes **38** that are perpendicular to the first longitudinal axis **26a**. A piston ring **40** is received in each of the ring grooves **36** of the first piston **64** and the first opposing piston **66** to seal the pair of first pistons **64, 66** against the cylinder wall **22**. At least one of the first inlet port **60** and the first exhaust port **62** has an oblique geometry **48** thereby defining at least one oblique port **60, 62**, which extends about the first cylinder **58a** in a path **50** that forms an oblique angle with the ring plane **38**. This staggers entry and exit times of the at least one piston ring **40** relative to the at least one port **60, 62** as the pair of first pistons **64, 66** translate within the first cylinder **58a**. The piston crown **34** of at least one piston **64, 66** has a periphery **52** that corresponds to the oblique geometry **48** of the at least one oblique port **60, 62** thereby defining at least one oblique piston crown **34**. The periphery **52** of the at least one oblique piston crown **34** opens and closes the at least one oblique port **60, 62** at substantially the same time along the oblique geometry **48** as the pair of first pistons **64, 66** translate within the first cylinder **58a**.

[0027] In some embodiments, including in the one shown in Figures 8 and 9, the first inlet port **60** and the first exhaust port **62** both have an oblique geometry **48**. Thus, the first inlet port **60** and the first exhaust port **62**

both extend at least partially about the first cylinder **58a** in a path **50** that is transverse to the ring plane **38** to stagger entry and exit times of the at least one piston ring **40** relative to each of the first inlet and exhaust ports **60, 62** as the pair of first pistons **64, 66** translate within the first cylinder **58a**. The periphery **52** of the piston crown **34** of the first piston **64** and the first opposing piston **66** may have a shape that corresponds to the oblique geometry **48** of the first inlet port **60** and the first exhaust port **62**. As a result, the periphery **52** of the piston crown **34** of the first piston **64** may open and close the first inlet port **60** at substantially the same time (i.e. evenly) along the oblique geometry **48** of the first inlet port **60** as the pair of first pistons **64, 66** translate within the first cylinder **58a**. Similarly, the periphery **52** of the piston crown **34** of the first opposing piston **66** may open and close the first exhaust port **62** at substantially the same time (i.e. evenly) along the oblique geometry **48** of the first exhaust port **62** as the pair of first pistons **64, 66** translate within the first cylinder **58a**.

[0028] The oblique geometry **48** of the piston crown **34** of the first piston **64** and the first opposing piston **66** may create a non-planar (i.e. uneven) periphery **52**. For example, the periphery **52** of the piston crown **34** of the first piston **64** may have high areas **68** and low areas **70**. The periphery **52** of the piston crown **34** of the first opposing piston **66** may also have high areas **68** and low areas **70**. In accordance with another aspect of the present disclosure, the first piston **64** and the first opposing piston **66** may be phased or rotated with respect to one another such that the high areas **68** of the first piston **64** interface with the low areas **70** of the first opposing piston **66** and the low areas **70** of the first piston **64** interface with the high areas **68** of the first opposing piston **66**. The first piston **64** may therefore nest with the first opposing piston **66** as the first piston **64** and the first opposing piston **66** approach one another during the first mode of operation. This nesting arrangement of the first piston **64** and the first opposing piston **66** is illustrated in Figure 9 where the pair of first pistons **64, 66** are shown in the top dead-center position. Advantageously, this allows for closer approach of the pair of first pistons **64, 66** to maximize compression within the first cylinder **58a** and decrease the overall length of the first cylinder **58a**.

[0029] With reference to Figure 10, the engine block **56** of the opposed-piston engine **54** may define a series of cylinders **58a, 58b, 58c, 58d, 58e, 58f**. Each cylinder **58a, 58b, 58c, 58d, 58e, 58f** includes a pair of pistons **30a, 30b, 30c, 30d, 30e, 30f** slidably disposed therein and selectively movable toward one another (Figure 9) and away from one another (Figure 8). Movement of the pistons **30a, 30b, 30c, 30d, 30e, 30f** relative to and within the cylinders **58a, 58b, 58c, 58d, 58e, 58f** drives a pair of crankshafts **74, 76** which, in turn, drive a gear train **78**. The gear train **78** may be connected to driven wheels of a vehicle (not shown), for example, whereby the pair of crankshafts **74, 76** and the gear train **78** cooperate to transform the linear motion of the pistons **30a, 30b, 30c,**

30d, 30e, 30f relative to the cylinders **58a, 58b, 58c, 58d, 58e, 58f** into rotational motion to allow the motion of the pistons **30a, 30b, 30c, 30d, 30e, 30f** to rotate the driven wheels and propel the vehicle.

[0030] The cylinders **58a, 58b, 58c, 58d, 58e, 58f** are housed within the engine block **56** and each includes a longitudinal axis **26a, 26b, 26c, 26d, 26e, 26f** that extends substantially perpendicular to an axis of rotation **104, 108** of each crankshaft **74, 76**. As shown in Figure 10, the cylinders **58a, 58b, 58c, 58d, 58e, 58f** may be offset from one another. The longitudinal axes **26a, 26c, 26e** of the cylinders **58a, 58c, 58e** are aligned with one another such that a primary cylinder plane **80** extends through each of the longitudinal axes **26a, 26c, 26e** that is substantially parallel to the axes of rotation **104, 108** of the crankshafts **74, 76**. Similarly, a secondary cylinder plane **82** intersecting longitudinal axes **26b, 26d, 26f** of the cylinders **58b, 58d, 58f** is substantially parallel to the axes of rotation **104, 108** of the crankshafts **74, 76**. The primary cylinder plane **80** is substantially parallel to and is offset from the secondary cylinder plane **82**, as the primary cylinder plane **80** is disposed on an opposite side of the plane extending through the axes of rotation **104, 108** of the crankshafts **74, 76** relative to the secondary cylinder plane **82**. Further, cylinder **58c** is disposed between cylinders **58a, 58e** and cylinder **58d** is disposed between cylinders **58b, 58f**. Accordingly, the configuration of the cylinders **58a, 58b, 58c, 58d, 58e, 58f** shown in Figure 10 creates a so-called "nested" arrangement, which allows the cylinders **58a, 58b, 58c, 58d, 58e, 58f** to be packaged in a smaller engine block **56**. Notwithstanding, it should be appreciated that the scope of the present disclosure is not limited to this number of cylinders **58a, 58b, 58c, 58d, 58e, 58f** or the configuration illustrated in Figure 10.

[0031] The cylinders **58a, 58b, 58c, 58d, 58e, 58f** of the opposed-piston engine **54** may be grouped into cylinder pairs **84, 86, 88** where cylinders **58a, 58b** are grouped in a first cylinder pair **84**, cylinders **58c, 58d** are grouped in a second cylinder pair **86**, and cylinders **58e, 58f** are grouped in a third cylinder pair **88**. Because the relative structure and function of the first cylinder pair **84** is the same as the second and third cylinder pairs **86, 88**, the following disclosure focuses on the first cylinder pair **84** with the understanding that the same also applies to the second and third cylinder pairs **86, 88** of the opposed-piston engine **54** illustrated in Figure 10.

[0032] With reference to Figures 11 and 12, a plurality of cylinder liners **90, 92** are disposed within the engine block **56**. Each cylinder liner of the plurality of cylinder liners **90, 92** defines a cylinder wall **22** that extends annularly about and defines a cylinder bore **24**. The plurality of cylinder liners **90, 92** includes a first cylinder liner **90** that defines a first cylinder **58a** and a second cylinder liner **92** that defines a second cylinder **58b**. With reference to Figure 11, the first cylinder **58a** has a first longitudinal axis **26a** that extends co-axially through the first cylinder **58a**. The first cylinder **58a** has a first inlet port

60 and a first exhaust port **62** that is longitudinally spaced from the first inlet port **60**. Both the first inlet port **60** and the first exhaust port **62** extend through the cylinder wall **22** of the first cylinder liner **90** and are arranged in fluid communication with the cylinder bore **24** of the first cylinder **58a**. A pair of first pistons **64, 66** including a first piston **64** and a first opposing piston **66** are slidably disposed within the first cylinder **58a** and are movable along the first longitudinal axis **26a**. For example, the pair of first pistons **64, 66** may move toward one another along the first longitudinal axis **26a** in a first mode of operation and away from one another along the first longitudinal axis **26a** in a second mode of operation as the pair of first pistons **64, 66** translate between a bottom dead-center position and a top dead-center position.

[0033] Referring now to Figure 12, the second cylinder **58b** has a second longitudinal axis **26b** that extends co-axially through the second cylinder **58b**. The second cylinder **58b** has a second inlet port **94** and a second exhaust port **96** that is longitudinally spaced from the second inlet port **94**. Both the second inlet port **94** and the second exhaust port **96** extend through the cylinder wall **22** of the second cylinder liner **92** and are arranged in fluid communication with the cylinder bore **24** of the second cylinder **58b**. The second cylinder **58b** is disposed adjacent to the first cylinder **58a** such that the first longitudinal axis **26a** of the first cylinder **58a** is parallel with and spaced from the second longitudinal axis **26b** of the second cylinder **58b**. Further, the first and second cylinders **58a, 58b** are arranged such that the first inlet port **60** of the first cylinder **58a** is longitudinally aligned with the second inlet port **94** of the second cylinder **58b** and such that the first exhaust port **62** of the first cylinder **58a** is longitudinally aligned with the second exhaust port **96** of the second cylinder **58b**.

[0034] A pair of second pistons **98, 100** including a second piston **98** and second opposing piston **100** are slidably disposed within the second cylinder **58b** and are movable along the second longitudinal axis **26b**. For example, the pair of second pistons **98, 100** may move toward one another in the first mode of operation and away from one another in the second mode of operation as the pair of second pistons **98, 100** translate between the bottom dead-center position and the top dead-center position. It should be appreciated that the first mode of operation and the second mode of operation occur sequentially during a single engine cycle.

[0035] Where the opposed-piston engine **54** is a two-stroke engine, the first mode of operation and the second mode of operation comprise the entirety of the single engine cycle. The intake charge is compressed during the first mode of operation and the intake charge ignites during the second mode of operation where the pistons **64, 66, 98, 100** are driven apart and where a new intake charge enters the cylinder bores **24** and the exhaust gases are expelled. Alternatively, where the opposed-piston engine **54** is a four-stroke engine, the single engine cycle may include two of the first modes of operation and two

of the second modes of operation. The single engine cycle may begin with the second mode of operation where the intake charge enters the cylinder bores **24** as the pistons **64, 66, 98, 100** move apart. The intake charge is then compressed in the first mode of operation where the pistons **64, 66, 98, 100** approach one another. The intake charge ignites and the combustion forces the pistons **64, 66, 98, 100** apart in another second mode of operation. Next, the pistons **64, 66, 98, 100** move in another first mode of operation where the pistons **64, 66, 98, 100** again approach one another to expel exhaust gases out of the cylinder bores **24**.

[0036] Referring to Figures 10-12, the pair of crankshafts **74, 76** includes a first crankshaft **74** and a second crankshaft **76**. The first crankshaft **74** is coupled to the first piston **64** of the pair of first pistons **64, 66** and to the second piston **98** of the pair of second pistons **98, 100** by a first pair of connecting rods **102**. The first crankshaft **74** rotates about a first axis of rotation **104** that is substantially perpendicular to the first longitudinal axis **26a** and the second longitudinal axis **26b**. Together, the first crankshaft **74** and the first pair of connecting rods **102** link movement of the first piston **64** with movement the second piston **98**. Preferably, movement of the first piston **64** opposes movement of the second piston **98** where the first crankshaft **74** is configured such that the second piston **98** moves in accordance with the second mode of operation when the first piston **64** is moving in accordance with the first mode of operation. In other words, the arrangement of the first crankshaft **74** and the first pair of connecting rods **102** is such that the second piston **98** moves towards the second opposing piston **100** when the first piston **64** is moving away from the first opposing piston **66**.

[0037] The second crankshaft **76** is coupled to the first opposing piston **66** of the pair of first pistons **64, 66** and to the second opposing piston **100** of the pair of second pistons **98, 100** by a second pair of connecting rods **106**. The second crankshaft **76** rotates about a second axis of rotation **108** that is substantially perpendicular to the first longitudinal axis **26a** and the second longitudinal axis **26b**. The second axis of rotation **108** of the second crankshaft **76** is also substantially parallel to and spaced from the first axis of rotation **104** of the first crankshaft **74**. Accordingly, the first cylinder **58a** and the second cylinder **58b** are generally positioned between the first crankshaft **74** and the second crankshaft **76**, although the first cylinder **58a** and the second cylinder **58b** are not necessarily in the same plane as the first and second crankshafts **74, 76**. Together, the second crankshaft **76** and the second pair of connecting rods **106** link movement of the first opposing piston **66** with movement the second opposing piston **100**. Preferably, movement of the first opposing piston **66** opposes movement of the second opposing piston **100** where the second crankshaft **76** is configured such that the second opposing piston **100** moves in accordance with the second mode of operation when the first opposing piston **66** is moving in accordance with

the first mode of operation. In other words, the arrangement of the second crankshaft **76** and the second pair of connecting rods **106** is such that the second opposing piston **100** moves towards the second piston **98** when the first opposing piston **66** is moving away from the first piston **64**. The opposed-piston engine **54** may include a gear train **78** that synchronizes rotation of the first and second crankshafts **74, 76** such that the first piston **64** and the first opposing piston **66** begin the first and second modes of operation at the same time and such that the second piston **98** and the second opposing piston **100** begin the first and second modes of operation at the same time.

[0038] Referring to Figure 11, a first combustion chamber **110** is disposed within the first cylinder **58a** between the first piston **64** and the first opposing piston **66**. A first fuel injector **112** may optionally be provided where the first fuel injector **112** extends through the cylinder wall **22** of the first cylinder liner **90** such that the first fuel injector **112** is disposed in fluid communication with the first combustion chamber **110**. Thus, the first fuel injector **112** may be operated to inject fuel into the first combustion chamber **110** during the first mode of operation. Where the opposed-piston engine **54** is a compression ignition engine, the fuel injected into the first combustion chamber **110** is compressed and ignites as the first piston **64** and the first opposing piston **66** approach one another. Alternatively, where the opposed-piston engine **54** is a spark ignition engine, a first spark plug **114** may be provided. The first spark plug **114** may generally extend through the cylinder wall **22** of the first cylinder liner **90** such that the first spark plug **114** is disposed in fluid communication with the first combustion chamber **110**. The first spark plug **114** may be operated to supply a spark to the first combustion chamber **110** to initiate combustion therein.

[0039] With reference to Figure 12, a second combustion chamber **116** is disposed within the second cylinder **58b** between the second piston **98** and the second opposing piston **100**. A second fuel injector **118** may optionally be provided where the second fuel injector **118** extends through the cylinder wall **22** of the second cylinder liner **92** such that the second fuel injector **118** is disposed in fluid communication with the second combustion chamber **116**. Thus, the second fuel injector **118** may be operated to inject fuel into the second combustion chamber **116** during the first mode of operation. Where the opposed-piston engine **54** is a compression ignition engine, the fuel injected into the second combustion chamber **116** is compressed and ignites as the second piston **98** and the second opposing piston **100** approach one another. Alternatively, where the opposed-piston engine **54** is a spark ignition engine, a second spark plug **120** may be provided. The second spark plug **120** may generally extend through the cylinder wall **22** of the second cylinder liner **92** such that the second spark plug **120** is disposed in fluid communication with the second combustion chamber **116**. The second spark plug **120** may

be operated to supply a spark to the second combustion chamber **116** to initiate combustion therein. As shown in Figures 10, 11, and 12, the fuel injectors **112**, **118** and the spark plugs **114**, **120** may be diametrically arranged relative to the cylinder bores **24**. Additionally, the first fuel injector **112** and the second spark plug **120** may be arranged on one side of the engine block **56** while the first spark plug **114** and the second fuel injector **118** are arranged on an opposite side of the engine block **56**. Of course other arrangements are possible and each cylinder may be equipped with multiple fuel injectors and/or spark plugs.

[0040] The first and second inlet ports **60**, **94** may be positioned longitudinally on one side of the first and second fuel injectors **112**, **118** and the first and second exhaust ports **62**, **96** may be positioned longitudinally on an opposite side of the first and second fuel injectors **112**, **118**. In Figures 10-12 for example, the first and second inlet ports **60**, **94** are to the right of the first and second fuel injectors **112**, **118** while the first and second exhaust ports **62**, **96** are to the left of the first and second fuel injectors **112**, **118**. An inlet manifold **122** may thus be arranged in fluid communication with the first inlet port **60** and the second inlet port **94**. The inlet manifold **122** shown in Figure 10 is at least partially disposed within the engine block **56** and transports air to the first inlet port **60** and the second inlet port **94** and thus the first and second combustion chambers **110**, **116** respectively. Similarly, an exhaust manifold **124** may be arranged in fluid communication with the first exhaust port **62** and the second exhaust port **96**. The exhaust manifold **124** shown in Figure 10 is at least partially disposed within the engine block **56** and transports exhaust expelled from the first and second combustion chambers **110**, **116** away from the first and second exhaust ports **62**, **96**.

[0041] The cylinder bore **24** of the first cylinder **58a** and the cylinder bore **24** of the second cylinder **58b** each has a bore cross-section **28** that is perpendicular to the first and second longitudinal axes **26a**, **26b**. The cylinder wall **22** of the first cylinder liner **90** and the cylinder wall **22** of the second cylinder liner **92** each includes an inner surface **32** facing the pair of first pistons **64**, **66** and the pair of second pistons **98**, **100** respectively. Each piston **64**, **66**, **98**, **100** of the pair of first pistons **64**, **66** and the pair of second pistons **98**, **100** has a piston crown **34** spanning the bore cross-section **28** and at least one ring groove **36** that extends annularly about each of the pistons **64**, **66**, **98**, **100** in a ring plane **38** that is perpendicular to the first and second longitudinal axes **26a**, **26b**. Thus, it should be appreciated that the bore cross-section **28** and the ring plane **38** are parallel to one another for each cylinder **58a**, **58b**, **58c**, **58d**, **58e**, **58f** and piston **30a**, **30b**, **30c**, **30d**, **30e**, **30f** in the opposed-piston engine **54**. A piston ring **40** is received in each ring groove **36** of each piston **30a**, **30b**, **30c**, **30d**, **30e**, **30f**. The piston rings **40** have an annular shape and extend radially from each of the pistons **30a**, **30b**, **30c**, **30d**, **30e**, **30f** within the ring plane **38** to seal against the inner surface **32** of

the cylinder wall **22**.

[0042] Each of the first and second inlet ports **60**, **94** and each of the first and second exhaust ports **62**, **96** include a plurality of windows **44** that are circumferentially spaced from one another about the cylinder wall **22**. Each window **44** of the plurality of windows **44** has a window perimeter **46** that extends about each window **44** of the plurality of windows **44** adjacent the inner surface **32** of the cylinder wall **22**. Accordingly, the window perimeters **46** of the plurality of windows **44** cooperatively form the first and second inlet ports **60**, **94** and the first and second exhaust ports **62**, **96**. Each of the first and second inlet ports **60**, **94** and each of the first and second exhaust ports **62**, **96** have an oblique geometry **48**. That is, each of the first and second inlet ports **60**, **94** and each of the first and second exhaust ports **62**, **96** extends circumferentially about the cylinder bore **24** in a path **50** that forms an oblique angle with the ring plane **38** to stagger entry and exit times of the piston rings **40** relative to the plurality of windows **44** the first and second inlet ports **60**, **94** and the first and second exhaust ports **62**, **96** as the pair of first pistons **64**, **66** and the pair of second pistons **98**, **100** reciprocate within the first cylinder **58a** and the second cylinder **58b** respectively. Therefore, the piston rings **40** cross the only some of the windows **44** of the first and second inlet ports **60**, **94** and only some of the windows **44** of the first and second exhaust ports **62**, **96** at any given moment in time so that ring clipping does not occur.

[0043] As shown in Figures 11 and 12, the piston crown **34** of each of the pistons **64**, **66**, **98**, **100** has a periphery **52** adjacent the cylinder wall **22** that forms an oblique angle with the ring plane **38** and that has a shape corresponding to the oblique geometry **48** of the first and second inlet ports **60**, **94** and the first and second exhaust ports **62**, **96**. Due to this shape, the periphery **52** of the piston crown **34** of the first and second pistons **64**, **98** opens and closes the first and second inlet ports **60**, **94** at substantially the same time (i.e. evenly) along their oblique geometry **48**. Likewise, this shape allows the periphery **52** of the piston crown **34** of the first and second opposing pistons **64**, **100** to open and close the first and second exhaust ports **62**, **96** at substantially the same time (i.e. evenly) along their oblique geometry **48**. The periphery **52** of the piston crown **34** of each of the pistons **64**, **66**, **98**, **100** may have high areas **68** and low areas **70**. Accordingly, the pair of first pistons **64**, **66** and the pair of second pistons **98**, **100** may be arranged to nest in the top dead-center position. For example, the first piston **64** and the first opposing piston **66** may be phased such that the high areas **68** of the first piston **64** interface with the low areas **70** of the first opposing piston **66** and the low areas **70** of the first piston **64** interface with the high areas **68** of the first opposing piston **66** when the pair of first pistons **64**, **66** are at the top dead-center position. The second piston **98** and the second opposing piston **100** may be similarly phased such that the high areas **68** of the second piston **98** interface with the low areas **70** of the second opposing piston **100** and the low

areas **70** of the second piston **98** interface with the high areas **68** of the second opposing piston **100** when the pair of second pistons **98, 100** are at the top dead-center position. Such an arrangement provides closer approach of the pistons **64, 66, 98, 100** at the top dead-center position and thus provides increased compression and packaging benefits. Notwithstanding, the oblique port geometry and the corresponding piston crown shape disclosed herein may be utilized without phasing the piston **64, 66, 98, 100** to nest with one another.

[0044] Many modifications and variations of the disclosed engine assembly **20** and opposed-piston engine **54** are possible in light of the above teachings and may be practiced otherwise than as specifically described while within the scope of the appended claims. These antecedent recitations should be interpreted to cover any combination in which the inventive novelty exercises its utility. The foregoing description of the embodiments has been provided for purposes of illustration and description. It is not intended to be exhaustive or to limit the disclosure. Individual elements or features of a particular embodiment are generally not limited to that particular embodiment, but, where applicable, are interchangeable and can be used in a selected embodiment, even if not specifically shown or described.

[0045] It follows a list of further embodiments:

1. An engine assembly comprising:

a cylinder wall extending about a cylinder bore, said cylinder bore defining a longitudinal axis;
a piston slidingly received within said cylinder bore that is movable along said longitudinal axis, said piston including at least one ring groove that extends about said piston in a ring plane that is transverse to said longitudinal axis;
at least one piston ring received in said at least one ring groove;
at least one port including a plurality of windows that extend through said cylinder wall, each window of said plurality of windows being open to said cylinder bore; and
said at least one port having an oblique geometry relative to said ring plane wherein said plurality of windows extend at least partially about said cylinder bore in a path that is oblique to said ring plane to stagger entry and exit times of said at least one piston ring relative to said plurality of windows as said piston reciprocates within said cylinder bore.

2. An engine assembly as set forth in embodiment 1 wherein said piston includes a piston crown having a periphery adjacent said cylinder wall that has a shape corresponding to said oblique geometry of said at least one port such that said periphery of said piston crown opens and closes said plurality of windows at substantially the same time along said ob-

lique geometry of said at least one port as said piston reciprocates within said cylinder bore.

3. An engine assembly as set forth in embodiment 2 wherein said oblique geometry of said at least one port and said shape of said periphery of said piston crown follows a sinusoidal path adjacent said cylinder wall.

4. An engine assembly as set forth in embodiment 2 wherein at least portions of said periphery of said piston crown are oblique to said ring plane.

5. An engine assembly as set forth in embodiment 2 wherein said cylinder bore has a bore cross-section that is perpendicular to said longitudinal axis and said piston crown spans said bore cross-section.

6. An engine assembly as set forth in embodiment 5 wherein said ring plane is parallel with said bore cross-section.

7. An engine assembly as set forth in embodiment 1 wherein said plurality of windows circumscribe said cylinder bore.

8. An engine assembly as set forth in embodiment 1 wherein said plurality of windows are circumferentially spaced from one another about said cylinder wall.

9. An engine assembly as set forth in embodiment 8 wherein each window of said plurality of windows has a window perimeter adjacent said cylinder wall where said window perimeter of each window in said plurality of windows defines said oblique geometry of said at least one port.

10. An engine assembly as set forth in embodiment 1 wherein said at least one port is an inlet port.

11. An engine assembly as set forth in embodiment 1 wherein said at least one port is an exhaust port.

12. An engine assembly comprising:

a cylinder wall extending annularly about and defining a cylinder bore;
said cylinder bore defining a longitudinal axis that extends co-axially through said cylinder bore;
said cylinder bore having a bore cross-section that is perpendicular to said longitudinal axis, said bore cross-section having a circular perimeter;
a piston slidingly received within said cylinder bore for reciprocal movement therein along said longitudinal axis between a bottom dead-center

position and a top dead-center position;
 said cylinder wall including an inner surface facing said piston;
 said piston including a piston crown spanning
 said bore cross-section and at least one ring
 groove that extends annularly about said piston
 in a ring plane that is perpendicular to said longitudinal axis and parallel to said bore cross-section;
 at least one piston ring received in said at least one ring groove, said piston ring having an annular shape and said at least one piston ring extending radially from said piston within said ring plane to seal against said inner surface of said cylinder wall;
 said cylinder wall having at least one port that includes a plurality of windows extending through said cylinder wall;
 each window of said plurality of windows being open to said cylinder bore and having a window perimeter extending about each window of said plurality of windows adjacent said inner surface of said cylinder wall;
 said at least one port having an oblique geometry relative to said ring plane where said plurality of windows are circumferentially spaced from one another about said cylinder bore in a path that is oblique to said ring plane to stagger entry and exit times of said at least one piston ring relative to said plurality of windows as said piston reciprocates within said cylinder bore between said bottom dead-center position and said top dead-center position; and
 said piston crown having a periphery adjacent said cylinder wall that is oblique to said ring plane and that has a shape corresponding to said oblique geometry of said at least one port such that said periphery of said piston crown opens and closes said plurality of windows at substantially the same time along said oblique geometry of said at least one port as said piston reciprocates within said cylinder bore between said bottom dead-center position and said top dead-center position.

13. An opposed-piston engine comprising:

an engine block including a cylinder wall that extends about and defines a first cylinder, said first cylinder having a first longitudinal axis and a first inlet port and a first exhaust port that is longitudinally spaced from said first inlet port;
 a pair of first pistons including a first piston and a first opposing piston that are slidably disposed within said first cylinder and that are movable along said first longitudinal axis toward one another in a first mode of operation and away from one another in a second mode of operation;

each piston of said pair of first pistons including a piston crown and at least one ring groove that extends about each piston of said pair of first pistons in a ring plane that is perpendicular to said first longitudinal axis;
 at least one piston ring received in said at least one ring groove of each piston of said pair of first pistons; and
 at least one of said first inlet port and said first exhaust port having an oblique geometry thereby defining at least one oblique port where said at least one oblique port includes a plurality of windows extending at least partially about said first cylinder in a path that is oblique to said ring plane to stagger entry and exit times of said at least one piston ring relative to said plurality of windows of said at least one oblique port as said pair of first pistons translate within said first cylinder.

14. An opposed-piston engine as set forth in embodiment 13 wherein said piston crown of at least one piston of said pair of first pistons has a periphery that corresponds to said oblique geometry of said at least one oblique port thereby defining at least one oblique piston crown where said periphery of said at least one oblique piston crown opens and closes said plurality of windows of said at least one oblique port at substantially the same time as said pair of first pistons translate within said first cylinder.

15. An opposed-piston engine as set forth in embodiment 14 wherein said oblique geometry of said at least one oblique port and said periphery of said at least one oblique piston crown follow a sinusoidal path adjacent said cylinder wall.

16. An opposed-piston engine as set forth in embodiment 13 wherein both of said first inlet and exhaust ports have said oblique geometry where each of said first inlet and exhaust ports have a plurality of windows that extend at least partially about said first cylinder in a path that is oblique to said ring plane to stagger entry and exit times of said at least one piston ring relative to said plurality of windows of each of said first inlet and exhaust ports as said pair of first pistons translate within said first cylinder.

17. An opposed-piston engine as set forth in embodiment 16 wherein said periphery of said piston crown of said first piston and said periphery of said piston crown of said first opposing piston have shapes that corresponds to said oblique geometry of said first inlet and exhaust ports such that said periphery of said piston crown of said first piston opens and closes said plurality of windows of said first inlet port at substantially the same time and such that said periphery of said piston crown of said first opposing

piston opens and closes said plurality of windows of said first exhaust port at substantially the same time as said pair of first pistons translate within said first cylinder.

18. An opposed-piston engine as set forth in embodiment 17 wherein said periphery of said piston crown of said first piston has high areas and low areas and said periphery of said piston crown of said first opposing piston has high areas and low areas.

19. An opposed-piston engine as set forth in embodiment 18 wherein said first piston and said first opposing piston are phased such that said high areas of said first piston interface with said low areas of said first opposing piston and said low areas of said first piston interface with said high areas of said first opposing piston so that said first piston and said first opposing piston nest with one another as said first piston and said first opposing piston approach one another during said first mode of operation.

20. An opposed-piston engine as set forth in embodiment 13 wherein said first inlet and exhaust ports each have a plurality of windows that circumscribe said first cylinder.

Claims

1. An engine assembly (20) comprising:

a cylinder wall (22) extending about a cylinder bore (24), said cylinder bore (24) defining a longitudinal axis (26, 26a);

a first piston (30, 64) slidably received within said cylinder bore (24) that is movable along said longitudinal axis (26, 26a), said first piston (30, 64) including at least one ring groove (36) that extends about said first piston (30, 64) in a ring plane (38) that is transverse to said longitudinal axis (26, 26a);

at least one piston ring (40) received in said at least one ring groove (36);

at least one port (42a, 42b) including a plurality of windows (44) that extend through said cylinder wall (22), each window of said plurality of windows (44) being open to said cylinder bore (24); and

said at least one port (42a, 42b) having an oblique geometry (48) relative to said ring plane (38) wherein said plurality of windows (44) extend at least partially about said cylinder bore (24) in a path (50) that is oblique to said ring plane (38) to stagger entry and exit times of said at least one piston ring (40) relative to said plurality of windows (44) as said piston (30, 64) reciprocates within said cylinder bore (24).

2. An engine assembly (20) as set forth in Claim 1, wherein said first piston (30, 64) includes a piston crown (34) having a periphery (52) adjacent said cylinder wall (22) that has a shape corresponding to said oblique geometry (48) of said at least one port (42a, 42b) such that said periphery (52) of said piston crown (34) opens and closes said plurality of windows (44) at substantially the same time along said oblique geometry (48) of said at least one port (42a, 42b) as said first piston (30, 64) reciprocates within said cylinder bore (24).

3. An engine assembly (20) as set forth in Claim 2, wherein said oblique geometry (48) of said at least one port (42a, 42b) and said shape of said periphery (52) of said piston crown (34) follows a sinusoidal path (50) adjacent said cylinder wall (22).

4. An engine assembly (20) as set forth in Claim 2 or 3, wherein at least portions of said periphery (52) of said piston crown (34) are oblique to said ring plane (38).

5. An engine assembly (20) as set forth in any of Claims 1 to 4, wherein said plurality of windows (44) circumscribe said cylinder bore (24).

6. An engine assembly (20) as set forth in any of Claims 1 to 5, wherein said plurality of windows (44) are circumferentially spaced from one another about said cylinder wall (22).

7. An engine assembly (20) as set forth in any of Claims 1 to 6, wherein each window (44) of said plurality of windows (44) has a window perimeter (46) adjacent said cylinder wall (22) where said window perimeter (46) of each window (44) in said plurality of windows (44) defines said oblique geometry (48) of said at least one port (42a, 42b).

8. An engine assembly (20) as set forth in any of Claim 1 to 7, wherein said at least one port (42a, 42b) is an inlet port (60).

9. An engine assembly (20) as set forth in any of Claims 1 to 8, wherein said at least one port (42, 42b) is an exhaust port (62).

10. An engine assembly (20) as set forth in any of Claims 1 to 9, further comprising:

a first opposing piston (66), slidably disposed within said cylinder bore (24), that opposes said first piston (30, 64) such that said first piston (30, 64) and said first opposing piston (66) are movable along said first longitudinal axis (26, 26a) toward one another in a first mode of operation and away from one another in a second mode

of operation, said first opposing piston (66) including at least one ring groove (36) that extends about said first opposing piston (66) in a ring plane (38) that is parallel to said ring plane (38) of said first piston (30, 64) and perpendicular to said longitudinal axis (26, 26a).

11. An engine assembly (20) as set forth in Claim 10, wherein said at least one port (42a, 42b) includes a first inlet port (60) and a first exhaust port (62), both of said first inlet (60) and exhaust ports (62) having said oblique geometry (48) where each of said first inlet (60) and exhaust ports (62) have a plurality of windows (44) that extend at least partially about said cylinder bore (24) in a path (50) that is oblique to said ring planes (38) of said first piston (30, 64) and said first opposing piston (66).
12. An engine assembly (20) as set forth in Claim 11, wherein each one of said first piston (30, 64) and said first opposing piston (66) has a piston crown (34) with a periphery (52), said periphery (52) of said piston crown (34) of said first piston (30, 64) and said periphery (52) of said piston crown (34) of said first opposing piston (66) each having a shape that corresponds to said oblique geometry (48) of said first inlet and exhaust ports (60, 62) such that said periphery (52) of said piston crown (34) of said first piston (30, 64) opens and closes said plurality of windows (44) of said first inlet port (60) at substantially the same time and such that said periphery (52) of said piston crown (34) of said first opposing piston (66) opens and closes said plurality of windows (44) of said first exhaust port (62) at substantially the same time as said first piston (30, 64) and said first opposing piston (66) translate within said cylinder bore (24).
13. An engine assembly (20) as set forth in Claim 12, wherein said periphery (52) of said piston crown (34) of said first piston (30, 64) and said periphery (52) of said piston crown (34) of said first opposing piston (66) have high areas (68) and low areas (70), wherein said first piston (30, 64) and said first opposing piston (66) are phased such that said high areas (68) of said first piston (30, 64) interface with said low areas (70) of said first opposing piston (66) and said low areas (70) of said first piston (30, 64) interface with said high areas (68) of said first opposing piston (66) so that said first piston (30, 64) and said first opposing piston (66) nest with one another as said first piston (30, 64) and said first opposing piston (66) approach one another during said first mode of operation.
14. An engine assembly (20) as set forth in any of Claims 10 to 13, wherein at least one of said first piston (30, 64) and said first opposing piston (66) has an oblique

piston crown (34) with a periphery (52) that corresponds to said oblique geometry (48) of said at least one port (42a, 42b) where said periphery (52) of said at least one oblique piston crown (34) opens and closes said plurality of windows (44) of said at least one port (42a, 42b) at substantially the same time.

15. An engine assembly (20) as set forth in Claim 14, wherein said oblique geometry (48) of said at least one port (42a, 42b) and said periphery (52) of said at least one oblique piston crown (34) follow a sinusoidal path (50) adjacent said cylinder wall (22).

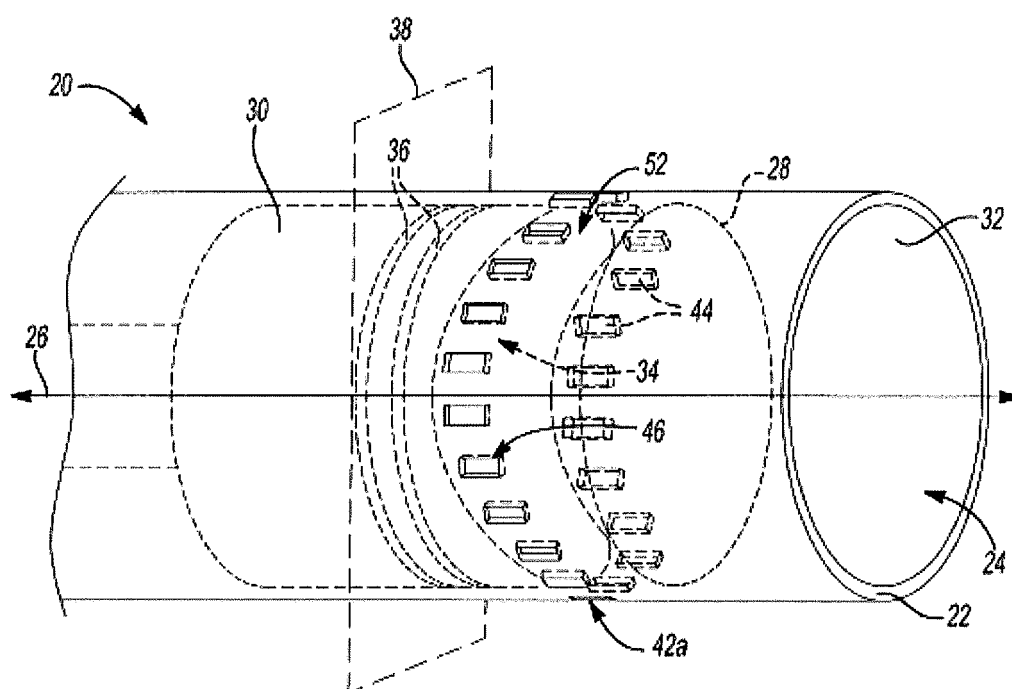


Fig-1

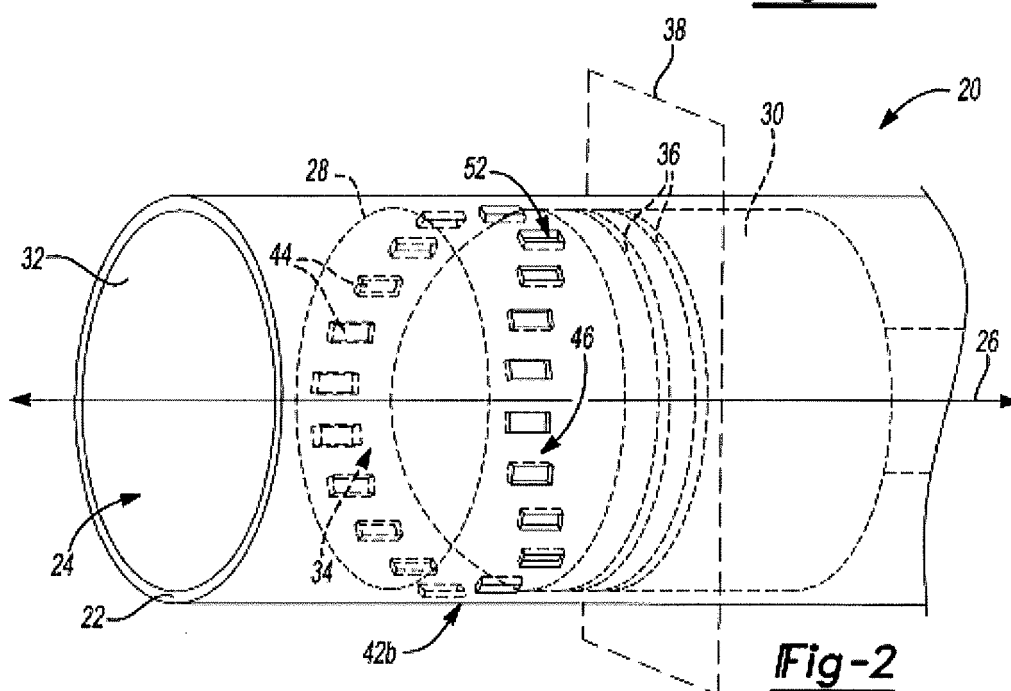


Fig-2

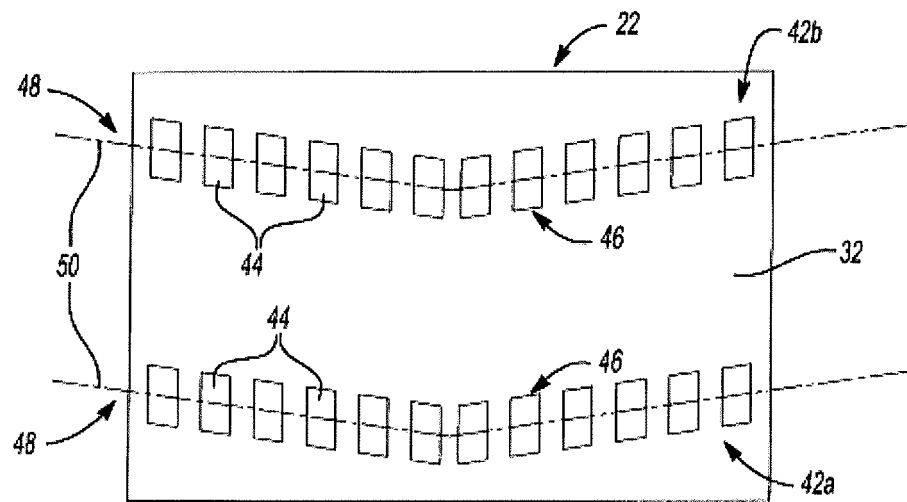


Fig-3

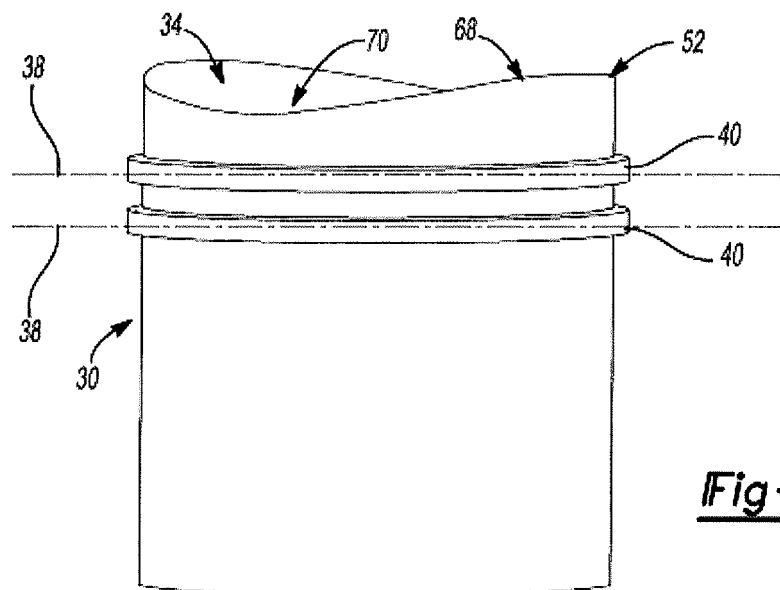


Fig-4

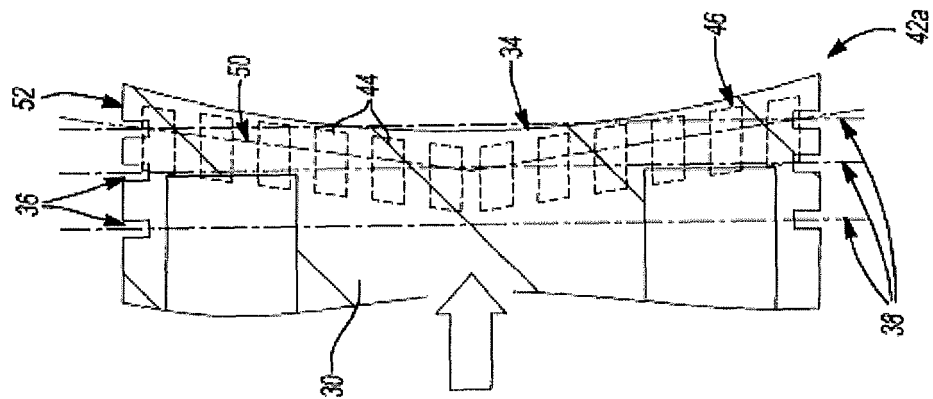


Fig-7

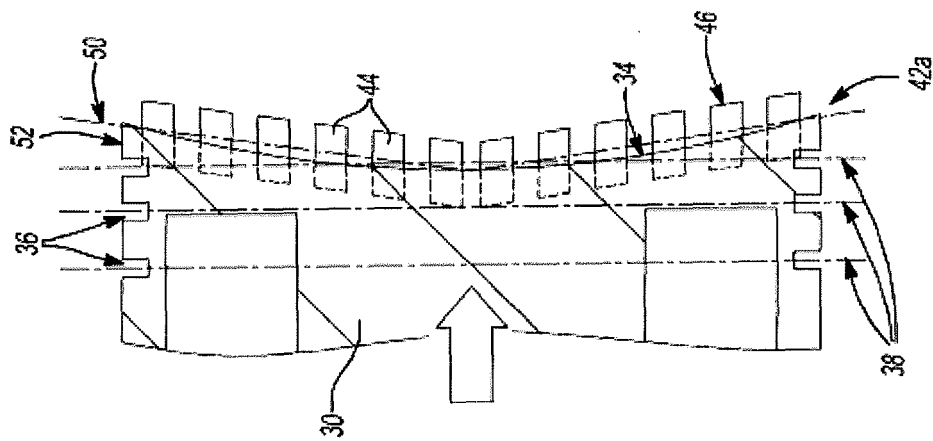


Fig-6

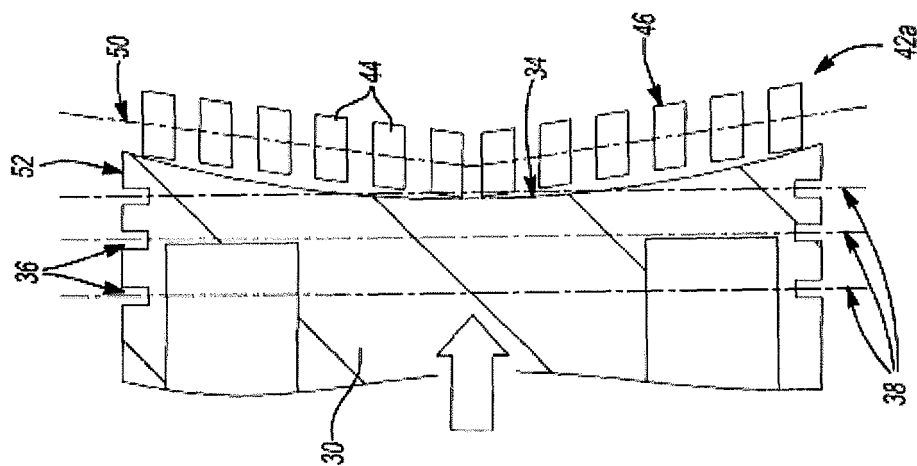
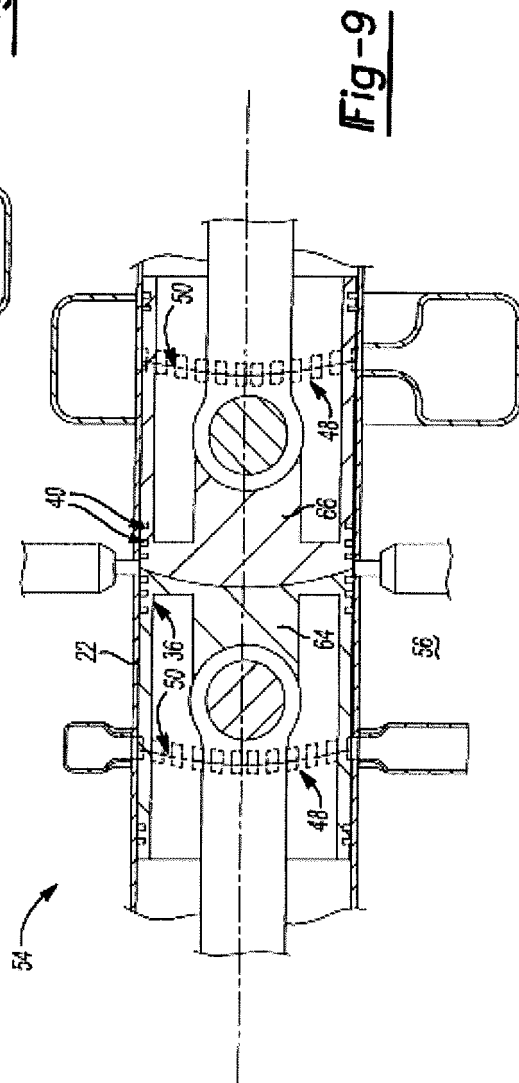
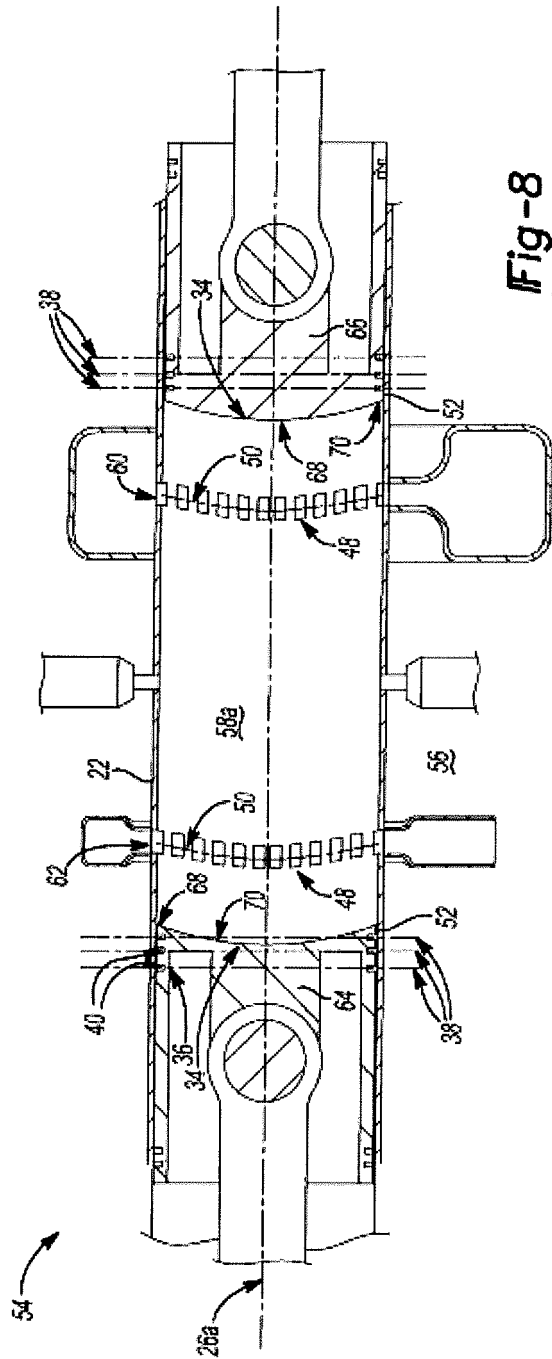


Fig-5



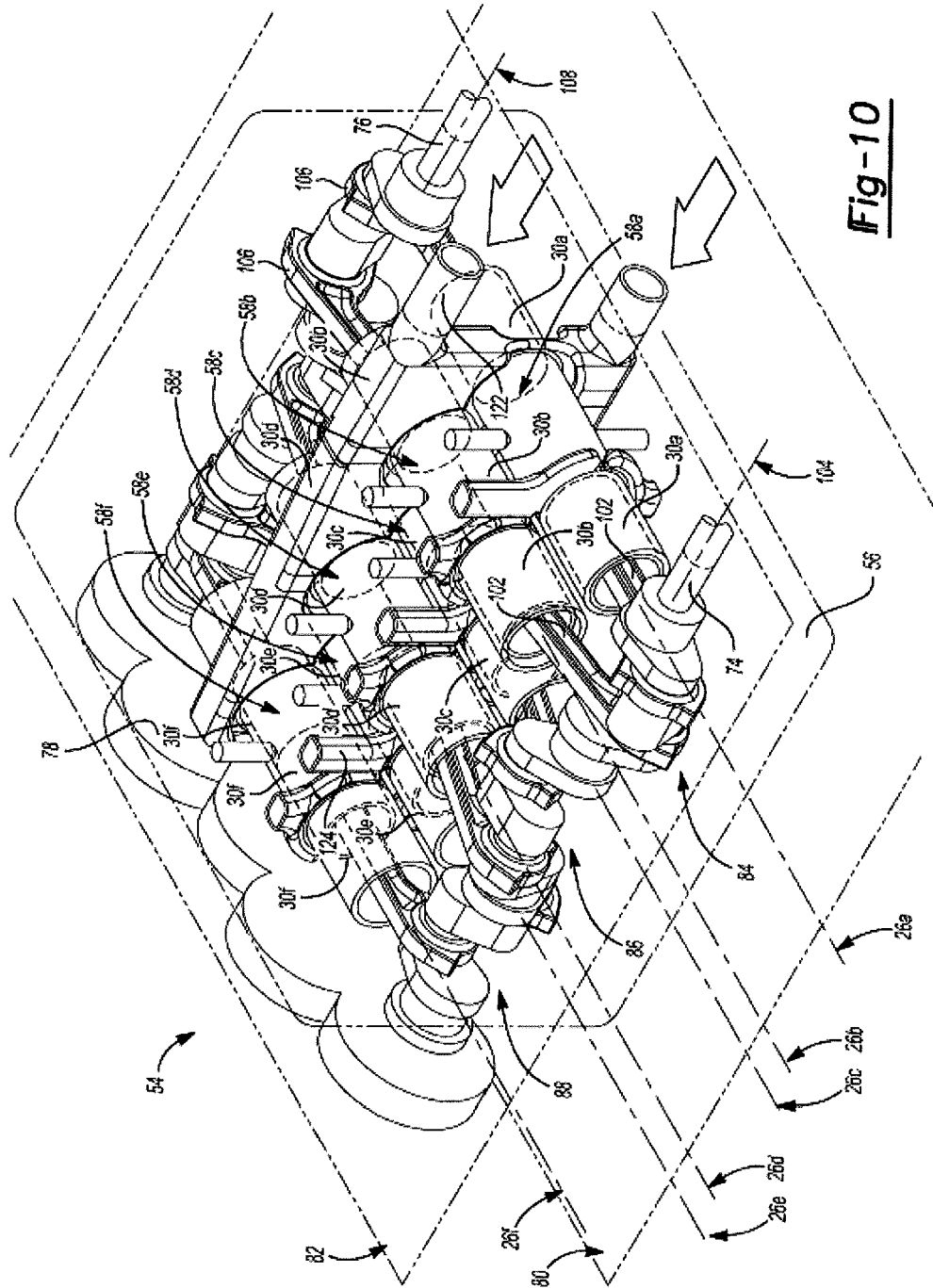


Fig-10

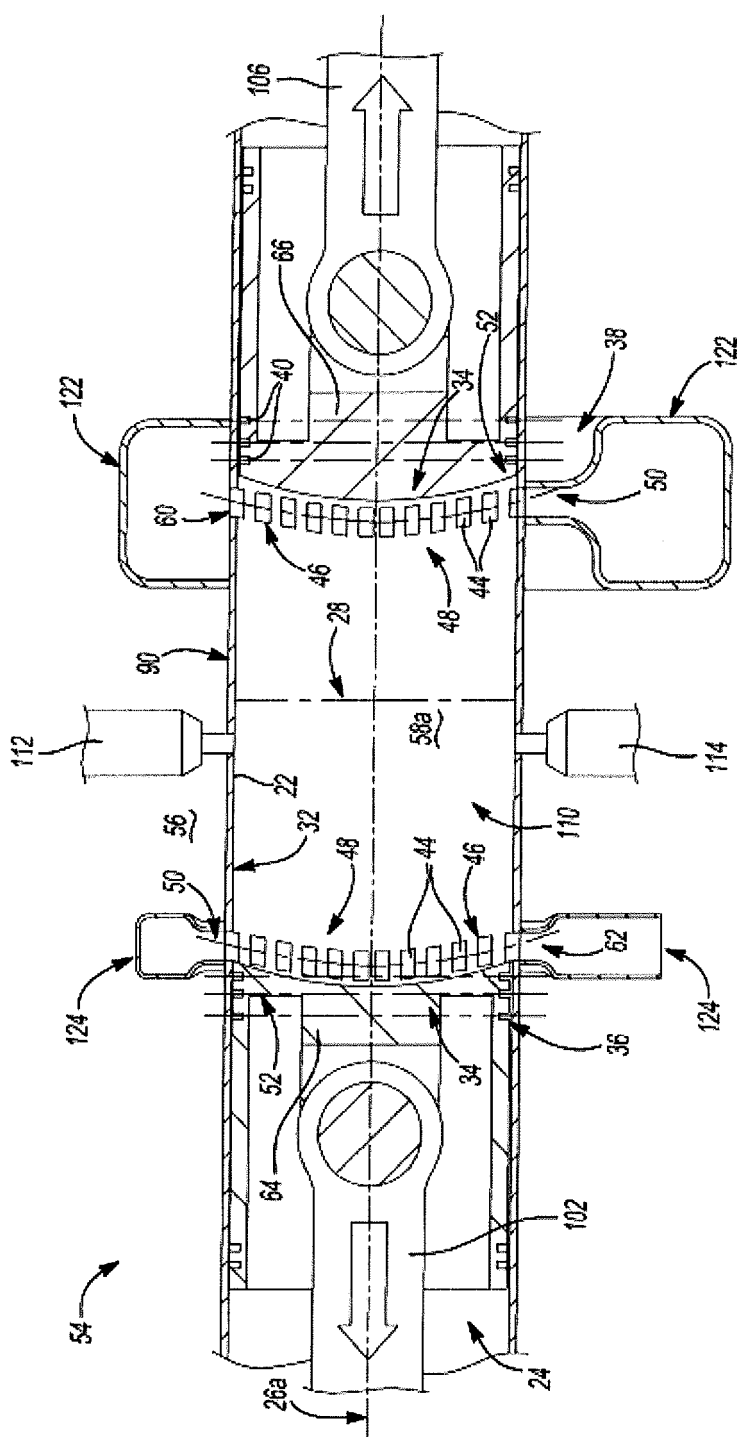


Fig-11

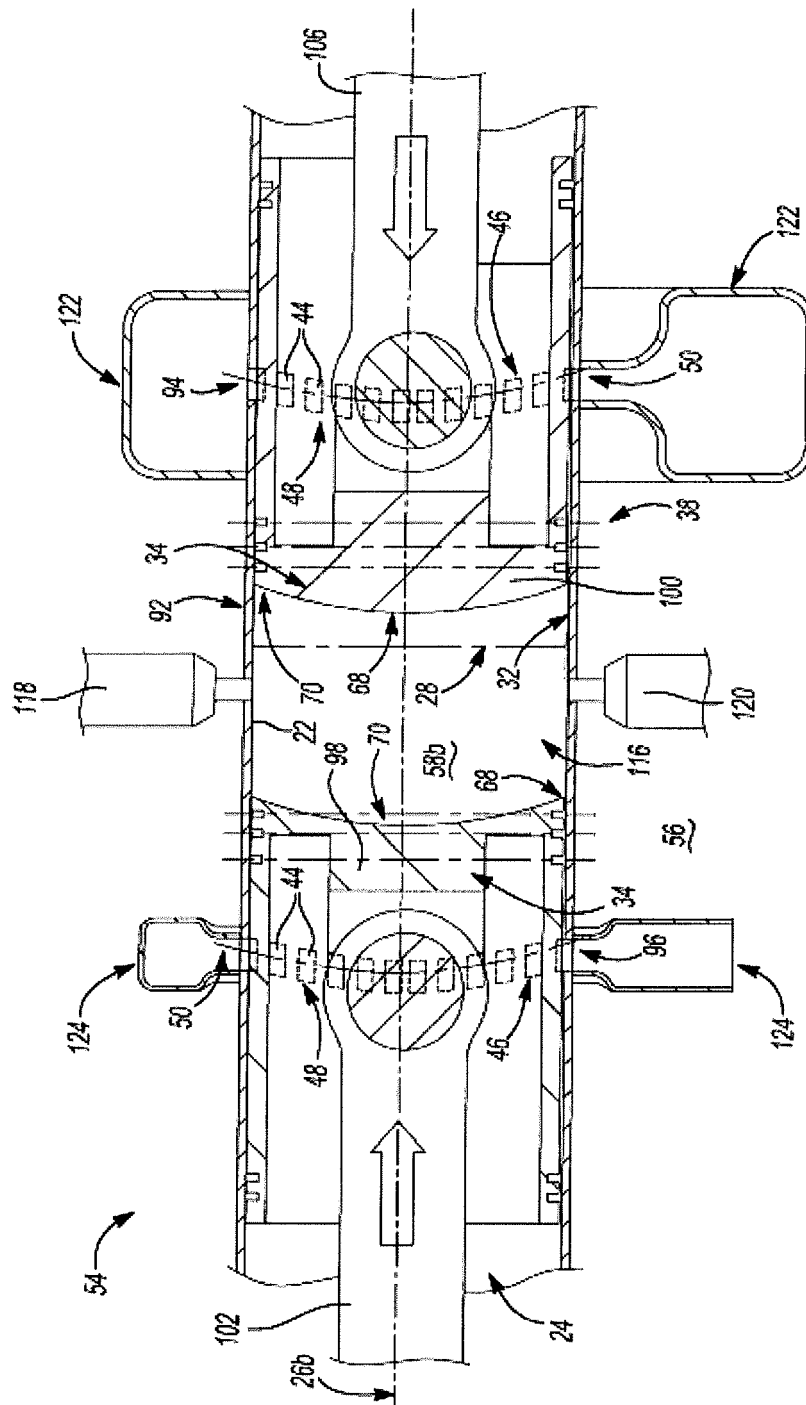


Fig-12



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Application Number
EP 16 15 7510

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			F02F F02B F01B
Place of search		Date of completion of the search	Examiner
Munich		17 June 2016	Coniglio, Carlo
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